Space Weather Technical Forecast

Issued on Sunday, 24 September 2023 at 01:22 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: Isolated M-flares likely, with a slight chance of X-flares (R1-R3 Radio blackouts). Chance of G1-G2 minor/moderate geomagnetic storms, most likely Day 1 (24 Sep).

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Moderate with one M-flare observed from over the northwest limb, peaking M1.5 at 23/2043 UTC. Frequent C-flares were also observed, including a C8.7 peaking 23/1518 UTC and a C7.7 peaking 23/0913 UTC, both from AR3445 in the southeast. This was the most active and developmental region on the disc, with ongoing flux emergence leading to a small delta spot developing. There are a total of eleven sunspot regions on the disc, with AR3443 in the northwest and AR3435 in the north-centre disc persisting as moderately sized regions, although less active than recent days. Despite this AR3435 remains notable as an anti-Hale cycle spot, while AR3443 maintained some slight complexity with a reverse polarity region following its main trailer spots. AR3441 in the northwest was the other notable region, also showing some flux emergence and a slightly more complex "beta-gamma" magnetic structure, but overall persisted as a small spot

A couple of weak CMEs were observed, including from the C7.7 flare, however these were all assessed as missing Earth.

Solar Wind / Geomagnetic Activity: Slow wind conditions persisted at L1 with observed solar wind speeds at background, around 370-320 km/s. The density remained around average or a little below. The Interplanetary magnetic field strength (IMF), Bt, was weak below 6nT, with the north-south component (Bz) also weak but predominately negative, ranging -6nT to +3nT. Phi angle was variable until around 23/1300 UTC, then mainly positive (away from the Sun). Resultant geomagnetic activity was Quiet to Unsettled (Kp 1-3).

Energetic Particles / Solar Radiation: GOES16 high energy (greater than 10MeV) proton flux was at background. GOES16 high energy (greater than 2MeV) electron flux was mainly Moderate, but rose to High briefly 23/0215-0315 and more persistently 23/1215-2015 UTC, with peak 2390 pfu at 23/1350 UTC. Associated 24-hour fluence was below the Active (1e8 integrated pfu) threshold, peaking 9.25e7 integrated pfu at 23/1500 UTC before declining again to reach 8.17e7 at 23/2100 UTC.

Four-Day Space Weather Forecast Summary

Solar Activity: Forecast to persist at Moderate with further isolated M-flares likely, and a slight chance of rising to High due to the potential for isolated X-flares from AR3445 in the southeast.

Solar Wind / Geomagnetic Activity: CME arrivals are possible through much of the period, with the most significant from the LP M1.2 flare early on 22 Sep, likely arriving day 1 (24 Sep). Confidence is low however, with a glancing impact most likely. There are also other possible weaker glancing impacts. This includes the CMEs from the M8.1 flare on 20 Sep (perhaps glancing early day 1) and from the M8.7 on 21 Sep (perhaps glancing later day 1 or day 2, 24-25 Sep). These may all be swept up by the main CME arrival however. Beyond this, there are a couple of further weak arrivals possible, due to filament eruptions also on 22 Sep, most likely

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arriving as a combined but glancing CME later on day 2 and into day 3 (25-26 Sep), however this is very low confidence. In the absence of any CME arrivals, mainly slow background winds are expected to persist. Geomagnetic activity is expected to be Quiet to Unsettled at first, but likely increasing to Active to G1 Minor Storm, with a chance of G2 Minor Storm intervals, with any CME arrivals, most likely day 1 (24 Sep), with a lower chance day 2-3 (25-26 Sep).

Energetic Particles / Solar Radiation: High energy (greater than 10 MeV) proton flux is expected to remain at Background levels, with a daily slight chance of an enhancement should any larger flares occur. High energy (greater than 2 MeV) electron flux has the potential to reach High levels on day 1 (24 Sep), before any CME arrival occurs, but then likely dropping out towards background. Flux then potentially recovering day 3-4 (26-27 Sep), depending on the strength of any impact. The associated fluence then rising, but with low confidence for reaching the Active (1e8 integrated pfu) threshold.

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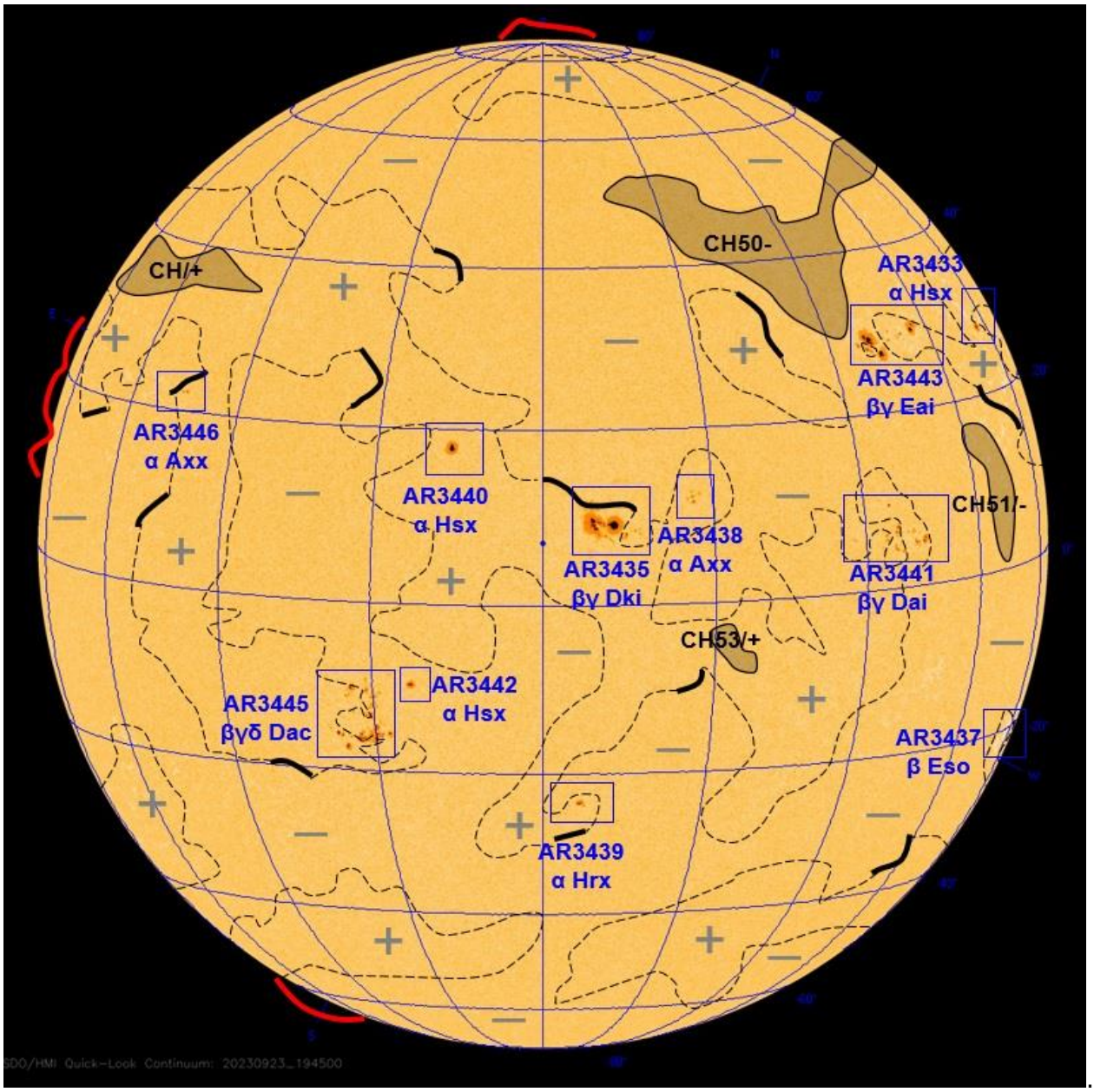
Figure 1. Solar Analysis Valid 23/2000 UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:

The geomagnetic forecast is currently low confidence due to the number of CME's that have recently left the Sun. The most significant CME is associated with the LP M1.2 flare, which peaked 22/0336 UTC. The anticipated arrival has been delayed slightly from previous expectations, now 24/1000 UTC +/- 10 hrs, albeit with much of the material likely passing behind (west) and north of Earth.

This may also be preceded by up to the CME from the M8.1 flare from AR3435 on 20 Sep, which was analysed as likely glancing Earth either late 23 or early 24 Sep, with low confidence in timing and has yet to arrive. A further CME from the M8.7 flare on 21 Sep was also analysed as likely arriving at Earth late on 24 or during 25 Sep (days 1-2). This is likely to be swept up into any arrival from the main CME mentioned above, but allows for an enhancement to occur should this CME miss. These CMEs all have very low confidence for their analysis.

There are also two further CMEs due to the coronal dimming events both early on 22 Sep. The first south of the AR3435/38 complex spot and a further one to the north of this region. These are both weak eruptions but give a slight chance of further enhancements on day 2/3 (25/26 Sep) but these are very low confidence. Other CMEs which feature in the forecast are from the double peak M1.5/1.4 flare at 23/1621 UTC and 23/1714 UTC of AR3443 in the northwest and from the M1.9 flare at 22/2300 UTC from AR3435/38. These CMEs are currently expected to be missing Earth but may give slight glancing impacts, potentially combined within the material in the aforementioned CMEs.

Overall this gives a very low confidence geomagnetic forecast, with potential for it to range from successive CMEs arrivals, giving Minor to Moderate geomagnetic storming (most likely day 1, 24 Sep) to Quieter conditions with solar winds dominated by either background slow winds, or any weak interaction with the fast winds of CH51/50. Although, having yet to occur, any connection to the HSS from these feature is now expected to be limited.

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	No	40	30	20	5
Strong	G3	No	10	5	1	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

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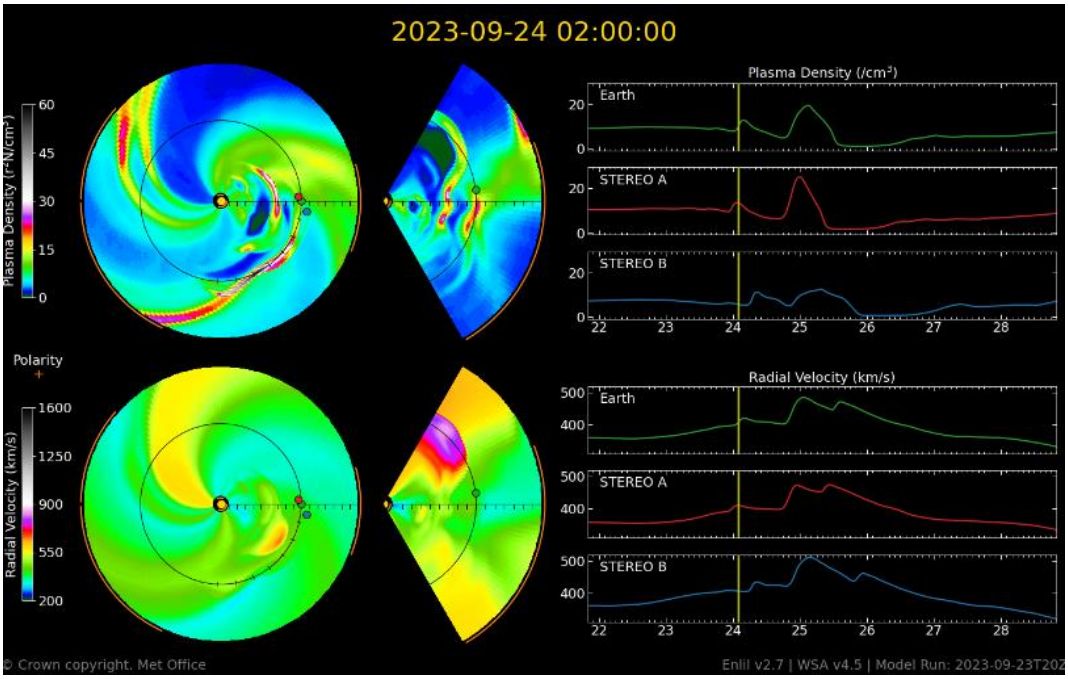
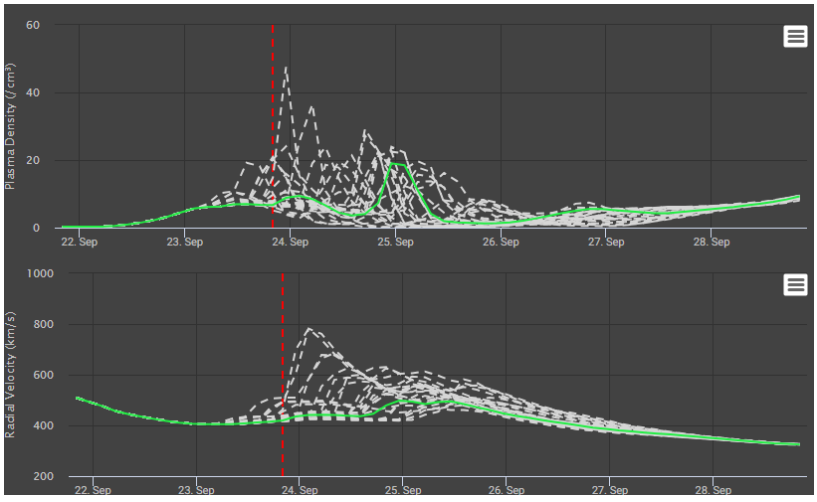
Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
20/2030	Partial	M8.1 AR3435	19S 27E	548 km/s	Early 24 Sep	Low confidence. Glancing
21/2024	Partial	M8.7 AR3435	20S 05E	480 km/s	Late 24-25 Sep	Low confidence. Glancing
22/0230	Partial	LP M1.2 AR3435	28N 24E	1225 km/s	24/1000 +/- 10hrs	Glancing (mostly missing)
22/1134	Partial	Filament	34N 13W	592 km/s	Late 25/26 Sep	Missing/ Glancing
22/1504	Partial	Filament	21S 12W	497 km/s	Late 25/26 Sep	Missing/ Glancing

Figure 2: Enlil and ensemble showing a sequence of potential CME arrivals





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Radio Blackouts - X-Ray Flares:

Moderate activity is expected with an ongoing likelihood of further M-flares through the period, and a slight chance of rising to High with the potential for isolated X-flares. There are eleven sunspot regions.

The most notable is AR3445 with an unstable delta configuration. This region is modestly sized, being comprised of a number of smaller spots, however some consolidation has occurred around the delta spot, with increasing magnetic flux strength. Imagery also shows notable magnetic looping across the spot, with a mobile flux rope visible in e.g. SDO aia-211, which would be a potential source for a significant reconnection, and subsequent notable flaring.

Of the other regions, AR3435 and AR3343 both persist as moderately sized regions, and were the main sources of recent activity, but have also shown recent signs of simplification. However AR3435 remains notable as an anti-Hale cycle sunspot, while AR3343 also has some complexity with a small reverse polarity region following its trailer. AR3341 is the other region of growth, albeit relatively slow, but with some limited complexity developing.

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	Yes	75	70	60	60
Very Active	R3 to R5 X Class	No	20	20	15	10

Figure 3: GOES 16/18 X-ray Flux

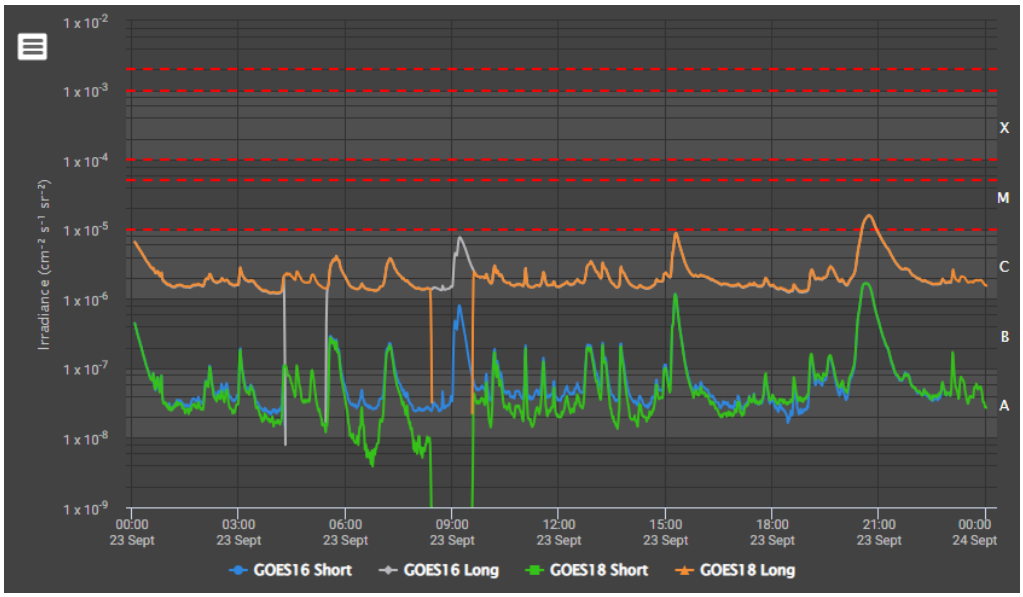

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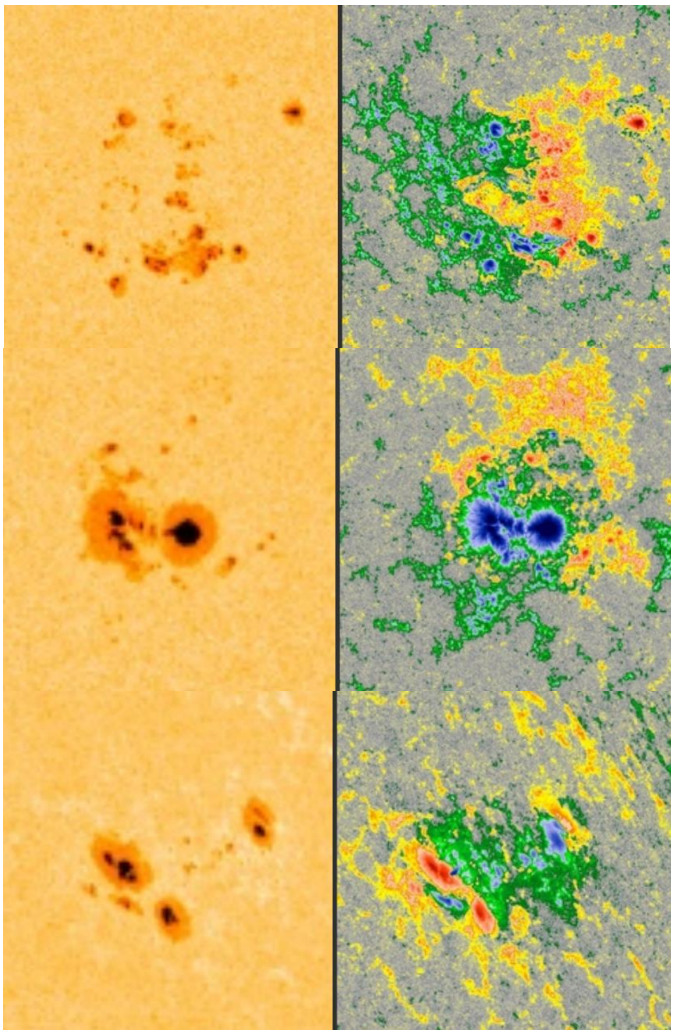
Figure 3b: SDO intensitygram/magnetogram of AR3445 (top) AR3335 (centre) and AR3443 (bottom)



Solar Radiation Storms - (High Energy Protons):

The high energy (greater than 10MeV) proton flux observed by GOES16 is likely to persist at background levels, however there are regions either on, or moving onto the western disc which bring a chance of flux levels rising above background given the occurrence of any significant flares. This includes AR3433, AR3435 and developing AR3445 in the southeast.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	No	15	15	10	10
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

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High Energy Electrons Event (≥ 2MeV):

High energy electron flux (greater than 2MeV) observed by GOES16 has been largely moderate to high, as enhanced electron levels at lower orbits expand outward to GEO. This has potentially peaked on 23 Sep, although a further spell of High flux is likely on day 1 (24 Sep) ahead of any CME arrival that may occur. These CME arrivals are likely to drop out values to background for a time, before a recovery later in the period, most likely day 3 or day 4 (26-27 Sep) bringing the potential for Moderate to High flux by the end of the period.

The associated 24 hour fluence likely peaked on 23 Sep, just below the Active threshold. While further increases are possible day 1 or 2 (24-25 Sep) the fluence is expected to persist below Active due to the reduced flux from the potential CME arrivals. There is then a slight, but increasing chance of fluence rising day 3-4 (26-27 Sep). REFM is currently giving good guidance of the expected trend, remaining below Active, albeit underestimating the current observed value. This will become poor when, and if, any CME arrival occurs.

GEO Electron Environment Probability (Exceedance)	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ 2 MeV ≥ $1x10^8$**	No	20	10	20	30
Very Active	**≥ 2 MeV ≥ $1x10^9$**	No	1	1	1	1

Figure 4: GOES 16>2MeV electron flux (top) and associated fluence with REFM (bottom)

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